

(19) World Intellectual Property Organization
International Bureau(43) International Publication Date
24 January 2002 (24.01.2002)

PCT

(10) International Publication Number
WO 02/05616 A1

(51) International Patent Classification: Not classified

(21) International Application Number: PCT/EP01/07829

(22) International Filing Date: 7 July 2001 (07.07.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data: 00115278.4 14 July 2000 (14.07.2000) EP

(71) Applicant (for all designated States except US): **BYK GULDEN LOMBERG CHEMISCHE FABRIK GMBH** [DE/DE]; Byk-Gulden-Strasse 2, 78467 Konstanz (DE).

(72) Inventors (for all designated States except CA, US): **BUNDSCUH, Daniela**; Rheingutstrasse 17, 78462 Konstanz (DE). **FLOCKERZI, Dieter**; Ackerweg 26, 78476 Allensbach (DE). **GRUNDLER, Gerhard**; Meersburger Str. 4, 78464 Konstanz (DE). **HATZELMANN, Armin**; Alter Wall 3, 78467 Konstanz (DE). **KLEY, Hans-Peter**; Im Weinberg 3b, 78476 Allensbach (DE).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **GUTTERER, Beate** [DE/DE]; Allensbacher Str. 5, 78476 Allensbach (DE).

(74) Common Representative: **BYK GULDEN LOMBERG CHEMISCHE FABRIK GMBH**; Byk-Gulden-Strasse 2, 78467 Konstanz (DE).

(81) Designated States (national): AE, AL, AU, BA, BG, BR, CA, CN, CO, CZ, EC, EE, GE, HR, HU, ID, IL, IN, JP, KR, LT, LV, MK, MX, NO, NZ, PL, RO, SG, SI, SK, UA, US, VN, YU, ZA, ZW.

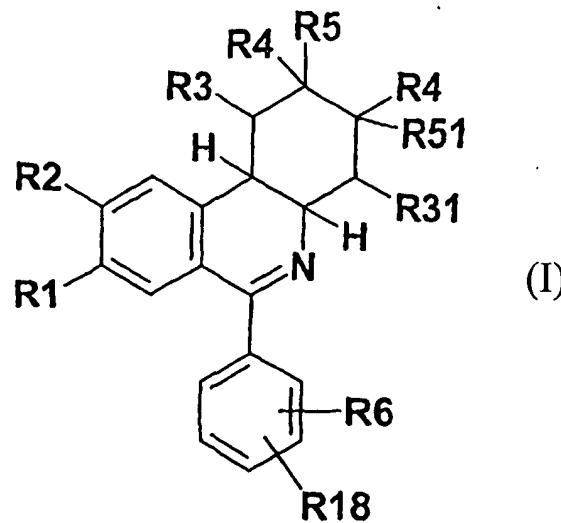
(84) Designated States (regional): Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

Published:

— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: NOVEL 6-PHENYLPHENANTHRIDINES



(57) Abstract: Compounds of the formula I, in which R6 is $\text{SO}_2\text{N}(\text{R7})\text{R8}$, COOR9 , $\text{CON}(\text{R10})\text{R11}$ or a R15-substituted tetrazol-5-yl radical, R18 is hydroxyl, halogen, nitro, amino, 1-4C-alkyl or 1-4C-alkoxy, or the salts, the N-oxide and the salts of the N-oxide of this compound, are active PDE4 inhibitors.

WO 02/05616 A1

Novel 6-phenylphenanthridines

Field of application of the invention

The invention relates to novel 6-phenylphenanthridines, which are used in the pharmaceutical industry for the production of medicaments.

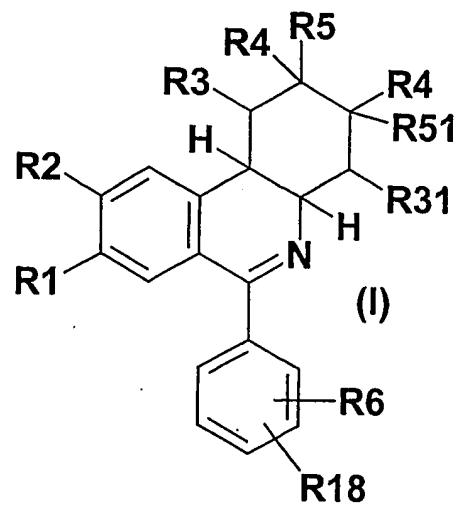
Known technical background

Chem.Ber. 1939, 72, 675-677, J. Chem. Soc., 1956, 4280-4283 and J. Chem. Soc.(C), 1971, 1805 describe the synthesis of 6-phenylphenanthridines. The International Applications WO 97/28131, WO 97/35854, WO 99/05111 and WO 99/05113 describe 6-phenyl- and 6-pyridylphenanthridines as PDE4 inhibitors.

Description of the invention

It has now been found that the novel 6-phenylphenanthridines described in greater detail below differ from the previously known 6-phenylphenanthridines by a different substitution pattern on the 6-phenyl ring and have surprising and particularly advantageous properties.

The invention thus relates to compounds of the formula I,



in which

R1 is hydroxyl, 1-4C-alkoxy, 3-7C-cycloalkoxy, 3-7C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R2 is hydroxyl, 1-4C-alkoxy, 3-7C-cycloalkoxy, 3-7C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-4C-alkoxy,

or in which

R1 and R2 together are a 1-2C-alkylenedioxy group,

R3 is hydrogen or 1-4C-alkyl,

R31 is hydrogen or 1-4C-alkyl,

or in which

R3 and R31 together are a 1-4C-alkylene group,

R4 is hydrogen or 1-4C-alkyl,

R5 is hydrogen,

R51 is hydrogen,

or in which

R5 and R51 together represent an additional bond,

R6 is $\text{SO}_2\text{N}(\text{R7})\text{R8}$, COOR9 , $\text{CON}(\text{R10})\text{R11}$ or a R15-substituted tetrazol-5-yl radical, where

R7 and R8 independently of one another are hydrogen, 1-7C-alkyl, 3-7C-cycloalkyl, 3-7C-cycloalkylmethyl or a phenyl radical which is unsubstituted or substituted by R12 and/or R13, or where R7 and R8 together and including the nitrogen atom to which both are bonded are a 1-pyrrolidinyl, 1-piperidyl, 1-hexahydroazepinyl or 4-morpholinyl radical,

R9 is hydrogen, 1-7C-alkyl, 3-7C-cycloalkyl or 3-7C-cycloalkylmethyl, and where either

R10 and R11 independently of one another are hydrogen, 1-7C-alkyl, 3-7C-cycloalkyl or 3-7C-cycloalkylmethyl,

or

R10 is hydrogen or 1-4C-alkyl and

R11 is a phenyl radical which is unsubstituted or substituted by R12 and/or R13 or a pyridyl radical which is unsubstituted or substituted by R14, where

R12 is hydroxyl, halogen, 1-4C-alkyl or 1-4C-alkoxy,

R13 is hydroxyl, halogen, nitro, cyano, carboxyl, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, 1-4C-alkoxycarbonyl, 1-4C-alkylcarbonyloxy, amino, mono- or di-1-4C-alkylamino, aminecarbonyl, mono- or di-1-4C-alkylaminocarbonyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R14 is halogen, nitro, carboxyl, 1-4C-alkoxy, 1-4C-alkoxycarbonyl, 1-4C-alkyl, trifluoromethyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R15 is hydrogen, 1-7C-alkyl, 3-7C-cycloalkyl, 3-7C-cycloalkylmethyl or Ar-1-4C-alkyl where Ar is a phenyl radical which is unsubstituted or substituted by R16 and/or R17, and

R16 and R17 independently of one another are halogen, nitro, cyano, 1-4C-alkyl, trifluoromethyl or 1-4C-alkoxy,

R18 is hydroxyl, halogen, nitro, amino, 1-4C-alkyl or 1-4C-alkoxy,

and the salts, the N-oxides and the salts of the N-oxides of these compounds.

1-7C-Alkyl represents straight-chain or branched alkyl radicals having 1 to 7 carbon atoms. Examples which may be mentioned are the heptyl, isoheptyl (5-methylhexyl), hexyl, isohexyl (4-methylpentyl),

neohexyl (3,3-dimethylbutyl), pentyl, isopentyl (3-methylbutyl), neopentyl (2,2-dimethylpropyl), butyl, isobutyl, sec-butyl, tert-butyl, propyl, isopropyl, ethyl and the methyl radical.

1-4C-Alkyl represents a straight-chain or branched alkyl radical having 1 to 4 carbon atoms. Examples which may be mentioned are the butyl, isobutyl, sec-butyl, tert-butyl, propyl, isopropyl and preferably the ethyl and methyl radicals.

1-4C-Alkoxy represents radicals which, in addition to the oxygen atom, contain a straight-chain or branched alkyl radical having 1 to 4 carbon atoms. Examples which may be mentioned are the butoxy, isobutoxy, sec-butoxy, tert-butoxy, propoxy, isopropoxy and preferably the ethoxy and methoxy radicals.

3-7C-Cycloalkoxy represents cyclopropyloxy, cyclobutyloxy, cyclopentyloxy, cyclohexyloxy and cycloheptyloxy, of which cyclopropyloxy, cyclobutyloxy and cyclopentyloxy are preferred.

3-7C-Cycloalkylmethoxy represents cyclopropylmethoxy, cyclobutylmethoxy, cyclopentylmethoxy, cyclohexylmethoxy and cycloheptylmethoxy, of which cyclopropylmethoxy, cyclobutylmethoxy and cyclopentylmethoxy are preferred.

As completely or predominantly fluorine-substituted 1-4C-alkoxy, for example, the 2,2,3,3,3-pentafluoropropoxy, the perfluoroethoxy, the 1,2,2-trifluoroethoxy, in particular the 1,1,2,2-tetrafluoroethoxy, the 2,2,2-trifluoroethoxy, the trifluoromethoxy and preferably the difluoromethoxy radicals may be mentioned. "Predominantly" in this connection means that more than half of the hydrogen atoms of the 1-4C-alkoxy radical are replaced by fluorine atoms.

1-2C-Alkylenedioxy represents, for example, the methylenedioxy [-O-CH₂-O-] and the ethylenedioxy [-O-CH₂-CH₂-O-] radicals.

If R3 and R31 together have the meaning 1-4C-alkylene, the positions 1 and 4 in compounds of the formula I are linked to one another by a 1-4C-alkylene bridge, 1-4C-alkylene representing straight-chain or branched alkylene radicals having 1 to 4 carbon atoms. Examples which may be mentioned are the radicals methylene [-CH₂-], ethylene [-CH₂-CH₂-], trimethylene [-CH₂-CH₂-CH₂-], 1,2-dimethylethylene [-CH(CH₃)-CH(CH₃)-] and isopropylidene [-C(CH₃)₂-].

If R5 and R51 together are an additional bond, then the carbon atoms in positions 2 and 3 in compounds of the formula I are linked to one another via a double bond.

Halogen within the meaning of the invention is bromine, chlorine or fluorine.

3-7C-Cycloalkyl represents cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl and cycloheptyl, of which cyclopropyl, cyclobutyl and cyclopentyl are preferred.

3-7C-Cycloalkylmethyl represents a methyl radical which is substituted by one of the abovementioned 3-7C-cycloalkyl radicals. Preferably, the 3-5C-cycloalkylmethyl radicals cyclopropylmethyl, cyclobutylmethyl and cyclopentylmethyl may be mentioned.

1-4C-Alkoxy carbonyl represents a carbonyl group to which one of the abovementioned 1-4C-alkoxy radicals is bonded. Examples which may be mentioned are the methoxycarbonyl [$\text{CH}_3\text{O}-\text{C}(\text{O})-$] and the ethoxycarbonyl [$\text{CH}_3\text{CH}_2\text{O}-\text{C}(\text{O})-$] radicals.

1-4C-Alkylcarbonyloxy represents a carbonyloxy group to which one of the abovementioned 1-4C-alkyl radicals is bonded. An example which may be mentioned is the acetoxy radical [$\text{CH}_3\text{C}(\text{O})-\text{O}-$].

In addition to the nitrogen atom, mono- or di-1-4C-alkylamino radicals contain one or two of the abovementioned 1-4C-alkyl radicals. Di-1-4C-alkylamino is preferred and here, in particular, dimethyl-, diethyl- or diisopropylamino.

In addition to the carbonyl group, mono- or di-1-4C-alkylaminocarbonyl radicals contain one of the abovementioned mono- or di-1-4C-alkylamino radicals. Examples which may be mentioned are the N-methyl-, the N,N-dimethyl-, the N-ethyl-, the N-propyl-, the N,N-diethyl- and N-isopropylaminocarbonyl radicals.

Ar-1-4C-alkyl represents one of the abovementioned 1-4C-alkyl radicals substituted by Ar.

Exemplary R6- and R18-substituted phenyl radicals which may be mentioned are 3-amino sulfonyl-4-chlorophenyl, 3-methoxycarbonyl-5-fluorophenyl, 3-fluoro-4-methoxycarbonylphenyl, 5-amino-3-methoxycarbonylphenyl, 5-amino-3-carboxyphenyl, 3-amino-4-carboxyphenyl, 3-amino-4-methoxycarbonylphenyl, 5-chloro-3-methoxycarbonylphenyl, 5-bromo-3-methoxycarbonylphenyl, 5-bromo-3-carboxyphenyl, 4-bromo-3-carboxyphenyl, 3-bromo-4-carboxyphenyl, 4-bromo-3-methoxycarbonylphenyl, 3-carboxy-5-hydroxyphenyl, 3-carboxy-5-methylphenyl, 3-ethoxycarbonyl-5-nitrophenyl, 4-methoxycarbonyl-3-nitrophenyl, 3-carboxy-4-nitrophenyl, 4-carboxy-3-nitrophenyl, 3-methoxycarbonyl-5-nitrophenyl, 3-carboxy-5-nitrophenyl, 5-tert-butyl-3-carboxyphenyl, 3-carboxy-4-hydroxyphenyl, 3-chloro-4-methoxycarbonylphenyl, 5-methylaminocarbonyl-3-nitrophenyl, 5-ethylaminocarbonyl-3-nitrophenyl and 4-[N-(3-nitrophenyl)carbamoyl]phenyl.

Possible salts for compounds of the formula I - depending on substitution - are all acid addition salts or all salts with bases. Particular mention may be made of the pharmacologically tolerable salts of the inorganic and organic acids and bases customarily used in pharmacy. Those suitable are, on the one

hand, water-soluble and water-insoluble acid addition salts with acids such as, for example, hydrochloric acid, hydrobromic acid, phosphoric acid, nitric acid, sulfuric acid, acetic acid, citric acid, D-gluconic acid, benzoic acid, 2-(4-hydroxybenzoyl)benzoic acid, butyric acid, sulfosalicylic acid, maleic acid, lauric acid, malic acid, fumaric acid, succinic acid, oxalic acid, tartaric acid, embonic acid, stearic acid, toluenesulfonic acid, methanesulfonic acid or 3-hydroxy-2-naphthoic acid, it being possible to employ the acids in salt preparation - depending on whether a mono- or polybasic acid is concerned and depending on which salt is desired - in an equimolar quantitative ratio or one differing therefrom.

On the other hand, salts with bases are also suitable. Examples of salts with bases which may be mentioned are alkali metal (lithium, sodium, potassium) or calcium, aluminum, magnesium, titanium, ammonium, meglumine or guanidinium salts, where here too the bases are employed in salt preparation in an equimolar quantitative ratio or one differing therefrom.

Pharmacologically intolerable salts which can initially be obtained, for example, as process products in the preparation of the compounds according to the invention on an industrial scale are converted into pharmacologically tolerable salts by processes known to the person skilled in the art.

It is known to the person skilled in the art that the compounds according to the invention and their salts, when they are isolated, for example, in crystalline form, can contain various amounts of solvents. The invention therefore also comprises all solvates and in particular all hydrates of the compounds of the formula I, and also all solvates and in particular all hydrates of the salts of the compounds of the formula I.

Compounds of the formula I to be emphasized are those in which

- R1 is 1-2C-alkoxy, 3-5C-cycloalkoxy, 3-5C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-2C-alkoxy,
- R2 is 1-2C-alkoxy, 3-5C-cycloalkoxy, 3-5C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-2C-alkoxy,
- R3 is hydrogen,
- R31 is hydrogen,
- R4 is hydrogen or 1-2C-alkyl,
- R5 is hydrogen,
- R51 is hydrogen,

or in which

R5 and R51 together represent an additional bond,

- R6 is $\text{SO}_2\text{N}(\text{R7})\text{R8}$, COOR9 , $\text{CON}(\text{R10})\text{R11}$ or a tetrazol-5-yl radical substituted by R15, where R7 and R8 independently of one another are hydrogen, 1-4C-alkyl, 3-7C-cycloalkyl, 3-7C-cycloalkylmethyl, or a phenyl radical which is unsubstituted or substituted by R12 and/or

R13, or where R7 and R8 together and including the nitrogen atom to which both are bonded are a 1-piperidyl or 4-morpholinyl radical,

R9 is hydrogen, 1-7C-alkyl or 3-7C-cycloalkylmethyl, and where either R10 and R11 independently of one another are hydrogen or 1-7C-alkyl or

R10 is hydrogen and

R11 is a phenyl radical which is unsubstituted or substituted by R12 and/or R13 or a pyridyl radical which is unsubstituted or substituted by R14, where

R12 is hydroxyl, halogen, 1-4C-alkyl or 1-4C-alkoxy,

R13 is hydroxyl, halogen, nitro, cyano, carboxyl, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, 1-4C-alkoxycarbonyl, 1-4C-alkylcarbonyloxy or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R14 is halogen, 1-4C-alkoxy, 1-4C-alkyl, trifluoromethyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R15 is hydrogen, 1-4C-alkyl, 5-7C-cycloalkyl, 3-7C-cycloalkylmethyl or Ar-1-2C-alkyl, where Ar is a phenyl radical which is unsubstituted or substituted by R16 and

R16 is 1-2C-alkyl or 1-2C-alkoxy,

R18 is halogen, nitro, 1-4C-alkyl or 1-4C-alkoxy,

and the salts, the N-oxides and the salts of the N-oxides of these compounds.

Compounds of the formula I particularly to be emphasized are those in which

R1 is 1-2C-alkoxy,

R2 is 1-2C-alkoxy,

R3, R31, R4, R5 and R51 are hydrogen,

R6 is $\text{SO}_2\text{N}(\text{R7})\text{R8}$, COOR9 , $\text{CON}(\text{R10})\text{R11}$ or an R15-substituted tetrazol-5-yl radical, where

R7 and R8 independently of one another are hydrogen, 1-4C-alkyl or a phenyl radical which is unsubstituted or substituted by R13,

R9 is hydrogen, 1-7C-alkyl or 3-7C-cycloalkylmethyl, and where either

R10 and R11 independently of one another are hydrogen or 1-4C-alkyl,

or

R10 is hydrogen and

R11 is a phenyl radical which is unsubstituted or substituted by R13 or a pyridyl radical which is unsubstituted or substituted by R14, where

R13 is halogen, nitro, cyano, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, 1-4C-alkoxy-carbonyl, 1-4C-alkylcarbonyloxy or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R14 is halogen, 1-4C-alkoxy, 1-4C-alkyl or trifluoromethyl,

R15 is hydrogen, 1-4C-alkyl or 4-methoxyphenyl,

R18 is halogen, nitro, 1-4C-alkyl or 1-4C-alkoxy,
and the salts, the N-oxides and the salts of the N-oxides of these compounds.

Preferred compounds of the formula I are those in which

R1 is 1-2C-alkoxy,

R2 is 1-2C-alkoxy,

R3, R31, R4, R5 and R51 are hydrogen,

R6 is $\text{SO}_2\text{N}(\text{R7})\text{R8}$, COOR9 or $\text{CON}(\text{R10})\text{R11}$, where

R7 and R8 independently of one another are hydrogen or 1-4C-alkyl,

R9 is hydrogen or 1-4C-alkyl,

R10 and R11 independently of one another are hydrogen or 1-4C-alkyl,

R18 is halogen, nitro, 1-4C-alkyl or 1-4C-alkoxy,

or the salts, the N-oxides and the salts of the N-oxides of this compound.

Particularly preferred compounds of the formula I are those in which

R1 is methoxy,

R2 is methoxy,

R3, R31, R4, R5 and R51 are hydrogen,

R6 is COOR9 , where

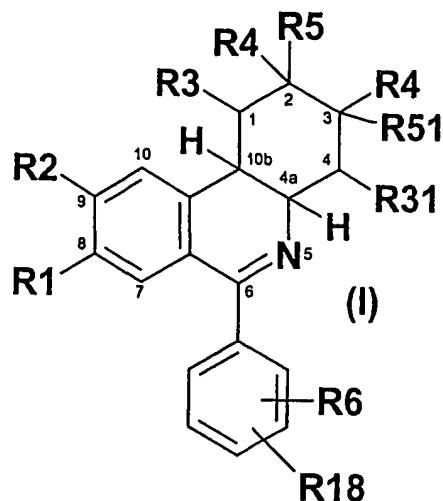
R9 is 1-4C-alkyl,

R18 is nitro,

and the salts, the N-oxides and the salts of the N-oxides of these compounds.

The compounds of the formula I are chiral compounds having chiral centers in positions 4a and 10b and, depending on the meaning of the substituents R3, R31, R4, R5 and R51, further chiral centers in the positions 1, 2, 3 and 4.

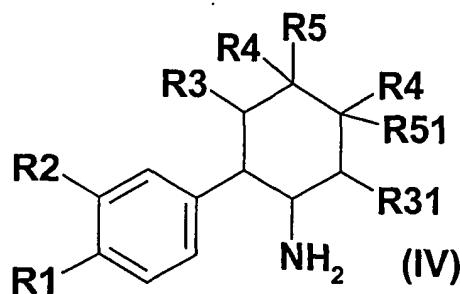
Numbering:



The invention therefore comprises all conceivable pure diastereomers and pure enantiomers and their mixtures in any mixing ratio, including the racemates. The compounds of the formula I are preferred in which the hydrogen atoms in positions 4a and 10b are cis to one another. The pure cis enantiomers are particularly preferred.

In this connection, particularly preferred compounds of the formula I are those in which positions 4a and 10b have the same absolute configuration as the compound (-)-cis-1,2-dimethoxy-4-(2-aminocyclohexyl)benzene employable as a starting compound and having the optical rotation $[\alpha]_D^{20} = -58.5^\circ$ ($c = 1$, ethanol).

The enantiomers can be separated in a manner known per se (for example by preparation and separation of appropriate diastereoisomeric compounds). Preferably, an enantiomer separation is carried out at the stage of the starting compounds of the formula IV

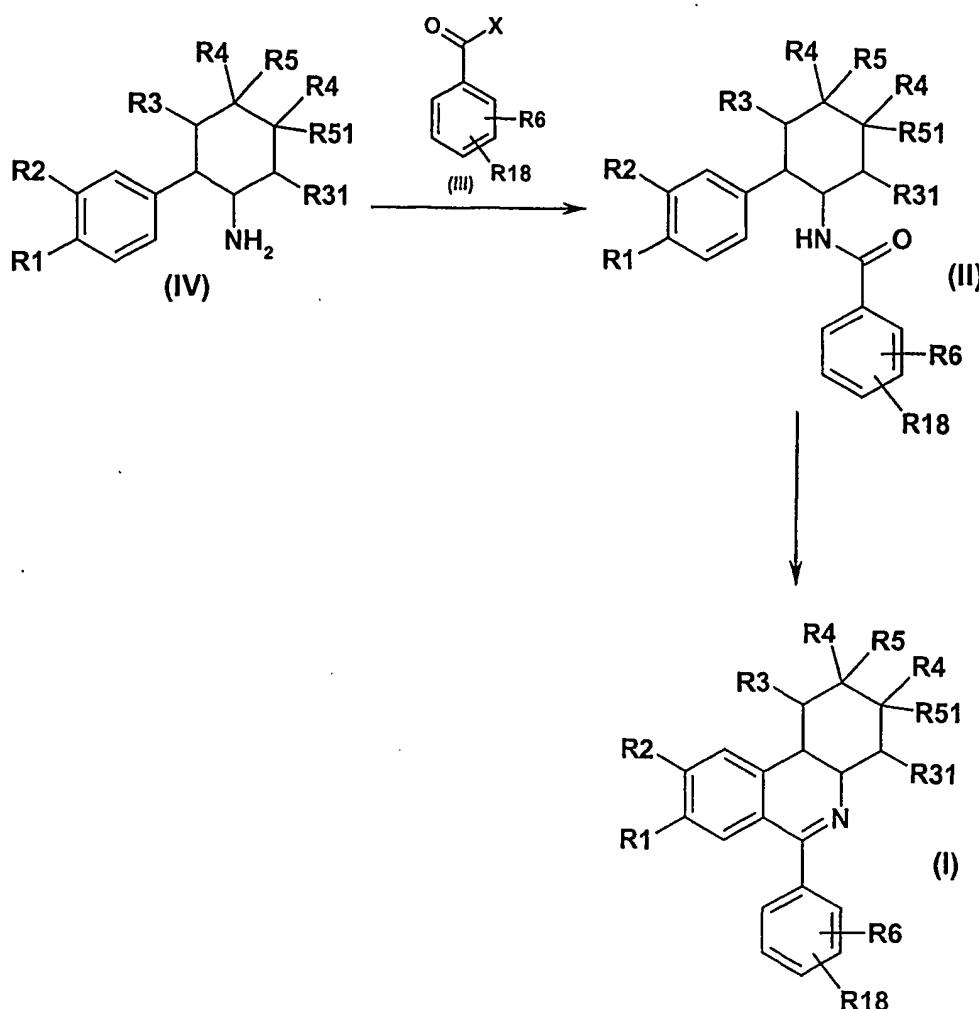


for example by means of salt formation of the racemic compounds of the formula IV with optically active carboxylic acids. Examples which may be mentioned in this connection are the enantiomeric forms of mandelic acid, tartaric acid, O,O'-dibenzoyltartaric acid, camphoric acid, quinic acid, glutamic acid, malic acid, camphorsulfonic acid, 3-bromocamphorsulfonic acid, α -methoxyphenylacetic acid,

α -methoxy- α -trifluoromethylphenylacetic acid and 2-phenylpropionic acid. Alternatively, enantiomerically pure starting compounds of the formula IV can also be prepared via asymmetric syntheses.

The preparation of the compounds of the formula I in which R1, R2, R3, R31, R4, R5, R51, R6 and R18 have the meanings indicated above and their salts can be carried out, for example, by the process described below in greater detail. In reaction scheme 1, a possible route for the preparation of compounds of the formula I is shown, in which R1, R2, R3, R31, R4, R5, R51 and R18 have the meanings indicated above and R6 is not an R15-substituted tetrazol-5-yl radical, but assumes one of the other abovementioned meanings. Reaction schemes 2 and 3 show preparation processes for compounds of the formula I in which R1, R2, R3, R31, R4, R5, R51 and R18 have the meanings indicated above and R6 is a R15-substituted tetrazol-5-yl radical.

Reaction scheme 1:



As reaction scheme 1 shows, the compounds of the formula I in which R1, R2, R3, R31, R4, R5, R51 and R18 have the meanings indicated above and R6 is not a R15-substituted tetrazol-5-yl radical, but is one of the other abovementioned meanings, are prepared from the compounds of the formula II by a cyclocondensation reaction.

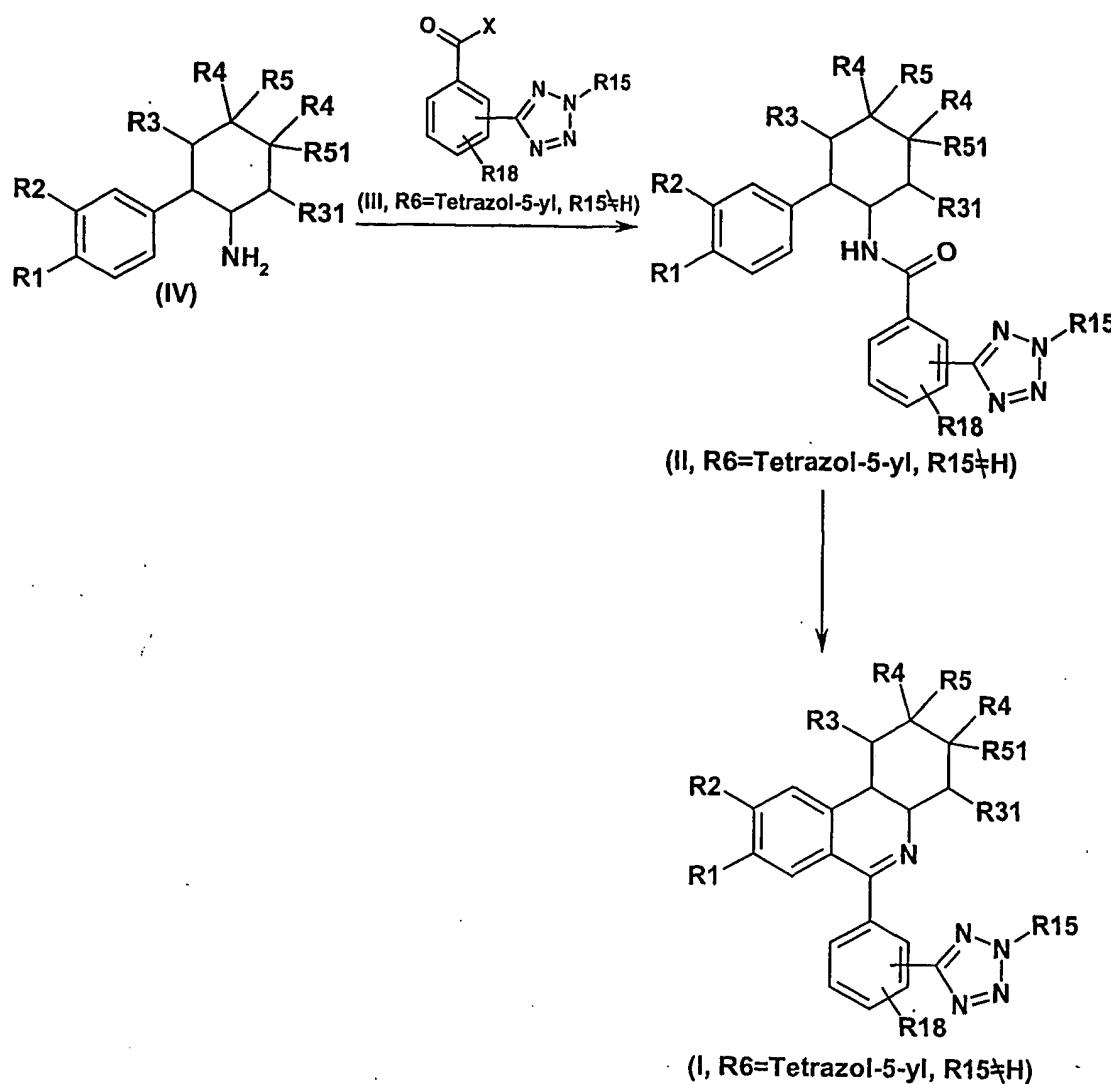
The cyclocondensation is carried out in a manner known per se to the person skilled in the art according to Bischler-Napieralski (e.g. as described in J. Chem. Soc., 1956, 4280-4282) in the presence of a suitable condensing agent, such as polyphosphoric acid, phosphorus pentachloride, phosphorus pentoxide or preferably phosphorus oxychloride, in a suitable inert solvent, e.g. in a chlorinated hydrocarbon such as chloroform, or in a cyclic hydrocarbon such as toluene or xylene, or another inert solvent such as acetonitrile, or without further solvent using an excess of condensing agent, preferably at elevated temperature, in particular at the boiling temperature of the solvent or condensing agent used.

The compounds of the formula II are obtained, for their part, by reaction of the compounds of the formula IV with compounds of the formula III, where X is a suitable leaving group, preferably a chlorine atom. For example, the acylation or benzoylation is carried out as described in the following examples or as in J. Chem. Soc. (C), 1971, 1805-1808.

Alternatively to the process described above, compounds of the formula II can also be prepared from the corresponding compounds of the formula IV and compounds of the formula III in which X is hydroxyl, by reaction with amide bond linking reagents known to the person skilled in the art. Exemplary amide bond linking reagents known to the person skilled in the art which may be mentioned are, for example, the carbodiimides (e.g. dicyclohexylcarbodiimide), azodicarboxylic acid derivatives (e.g. diethyl azodicarboxylate), uronium salts [e.g. O-(benzotriazol-1-yl)-N,N,N',N'-tetramethyluronium tetrafluoroborate] and N,N'-carbonyldiimidazole.

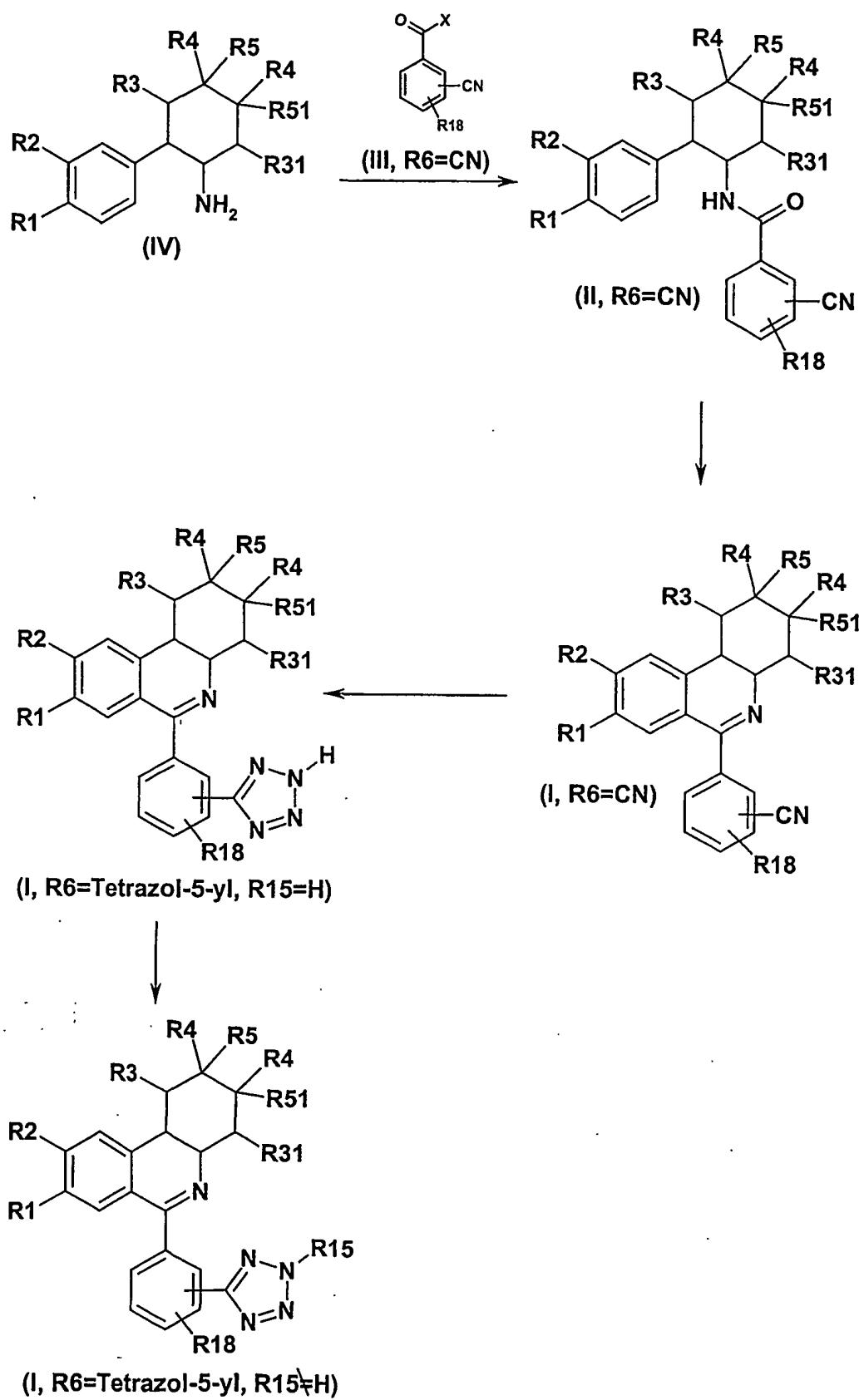
This alternative preparation process is particularly suitable for the preparation of compounds of the formula II in which R18 is amino or hydroxyl.

Reaction scheme 2:



Reaction scheme 2 shows one of the possible preparation routes for compounds of the formula I in which R₁, R₂, R₃, R₃₁, R₄, R₅, R₅₁ and R₁₈ have the meanings indicated above and R₆ is a tetrazol-5-yl radical substituted by a radical R₁₅ (R₁₅ ≠ hydrogen). In the same way as described in reaction scheme 1, the compounds of the formula I are prepared from compounds of the formula II by a cyclocondensation reaction. The compounds of the formula II, for their part, are obtained by reaction of the compounds of the formula IV with compounds of the formula III.

Reaction scheme 3:



Reaction scheme 3 shows a preparation route to compounds of the formula I in which R1, R2, R3, R31, R4, R5, R51 and R18 have the meanings indicated above and R6 is a tetrazol-5-yl radical substituted by a radical R15 (R15 = hydrogen). Moreover, reaction scheme 3 shows a preparation process for compounds of the formula I which is alternative to reaction scheme 2, in which R1, R2, R3, R31, R4, R5, R51 and R18 have the meanings indicated above and R6 is a tetrazol-5-yl radical substituted by a radical R15 (R15 ≠ hydrogen).

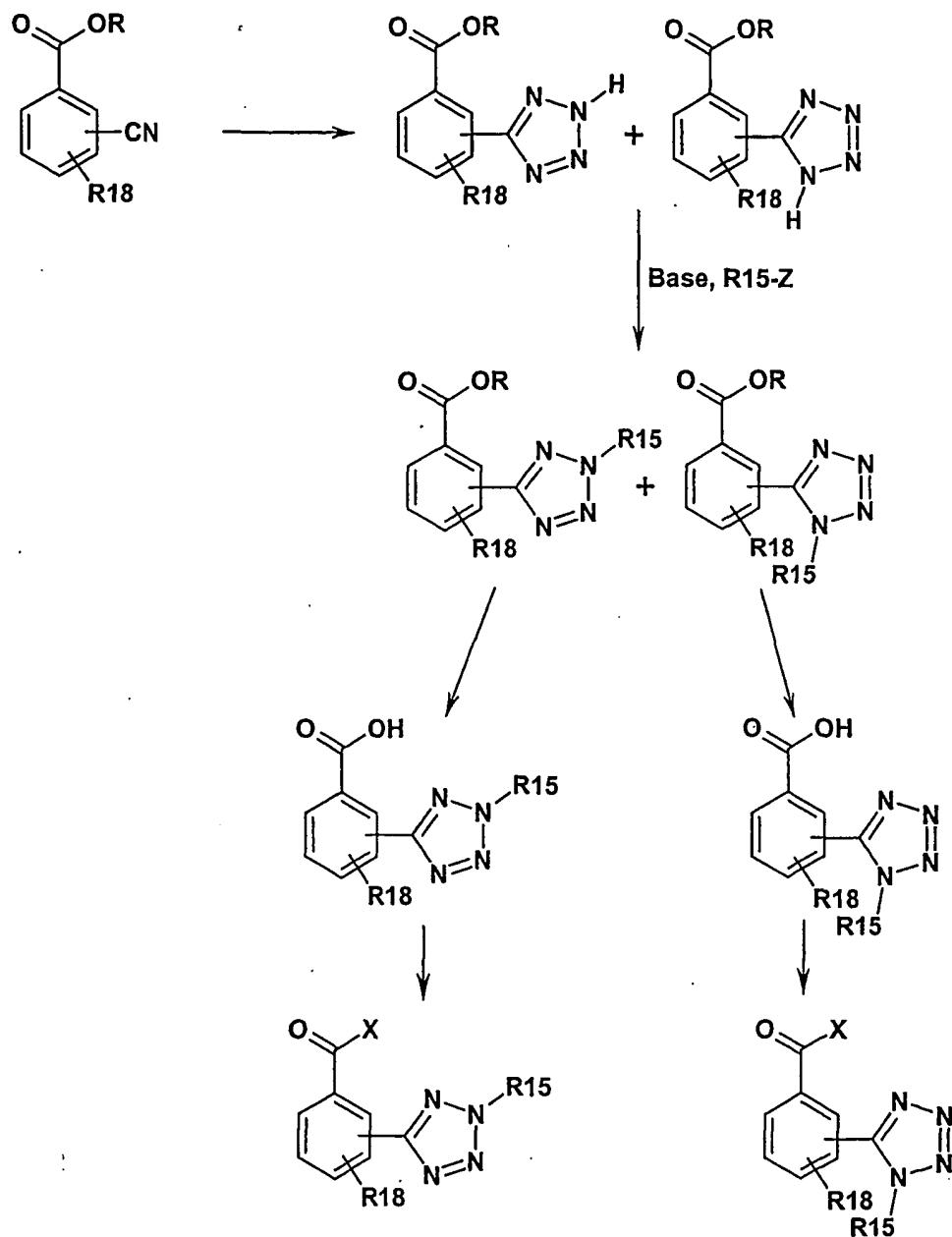
As reaction scheme 3 shows, the compounds of the formula I in which R1, R2, R3, R31, R4, R5, R51 and R18 have the meanings indicated above and R6 is a tetrazol-5-yl radical which is substituted by a radical R15 (R15 = hydrogen) are prepared from corresponding compounds of the formula I in which R6 is cyano by reaction with alkali metal azides and halogen salts of ammonia. The compounds of the formula I in which R6 is cyano are in turn obtained by cyclocondensation reaction from the corresponding compounds of the formula II. Analogously to reaction schemes 1 and 2, the compounds of the formula II are obtained by reaction of the compounds of the formula IV with compounds of the formula III in which X is a suitable leaving group, preferably a chlorine atom.

Alternatively to the route shown in reaction scheme 2, compounds of the formula I in which R1, R2, R3, R31, R4, R5, R51 and R18 have the meanings indicated above and R6 is a tetrazol-5-yl radical substituted by a radical R15 (R15 ≠ hydrogen) can also be prepared by an alkylation reaction from the corresponding compounds of the formula I in which R15 is hydrogen. The alkylation reaction is expediently carried out analogously to the methods known to the person skilled in the art, e.g. by reaction of the 1H- and 2H-tetrazole compounds of the formula I with compounds of the formula R15-Z in the presence of a base, where R15 has the abovementioned meanings - excluding hydrogen - and Z is a suitable leaving group such as a chlorine, bromine or iodine atom or an alkylsulfate radical. The 1- and 2-substituted tetrazole regioisomer mixtures usually formed in the alkylation are separated by methods known to the person skilled in the art, such as crystallization or chromatography on suitable carrier materials. An analogous alkylation of tetrazoles and separation of the regioisomers is described, for example, in *J. Med. Chem.* **1996**, 39, 2354.

The reaction of cyanophenyl derivatives with alkali metal azides and halogen salts of ammonia to give 2-, 3- or 4-(1H- or 2H-tetrazol-5-yl)phenyl derivatives unsubstituted in the tetrazole moiety is described, for example, in *J. Med. Chem.* **1993**, 36, 3246.

Compounds of the formula III are either known or can be prepared in a known manner.

Reaction scheme 4:



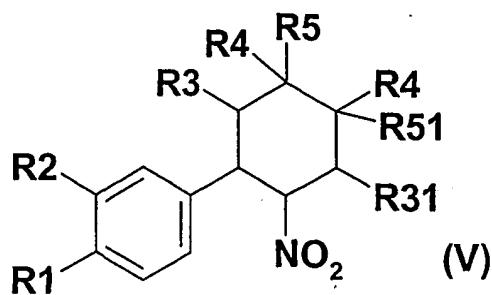
Reaction scheme 4 discloses a possible preparation route for compounds of the formula III in which X is a suitable leaving group, preferably a chlorine atom, R18 has the abovementioned meanings and R6 is a tetrazol-5-yl radical substituted by a radical R15 ($R15 \neq$ hydrogen). Starting from alkyl 2-, 3- or 4-cyanobenzoates, 2-, 3- or 4-(1H and 2H-tetrazol-5-yl)benzoic acid ester derivatives unsubstituted in the tetrazole moiety are obtained in a manner known to the person skilled in the art, e.g. by reaction with alkali metal azides and halogen salts of ammonia. Such a reaction is described, for example, in J. Med. Chem. 1993, 36, 3246. These intermediate compounds are then subjected to an alkylation reaction, the regioisomers are separated by methods known to the person skilled in the art, such as crystal-

lization or chromatography on suitable carrier materials, the ester group is hydrolyzed and finally the suitable leaving group is introduced.

It is known to the person skilled in the art that in the case of a number of reactive centers on a starting or intermediate compound it may be necessary to block one or more reactive centers temporarily by protective groups in order to allow a reaction to proceed specifically at the desired reaction center. A detailed description of the use of a large number of proven protective groups is found, for example, in T.W. Greene, *Protective Groups in Organic Synthesis*, John Wiley & Sons, 1991.

In addition, the compounds of the formula I can be converted, if desired, into their N-oxides, for example with the aid of hydrogen peroxide in methanol or with the aid of m-chloroperoxybenzoic acid in dichloromethane. The person skilled in the art is familiar on the basis of his/her expert knowledge with the reaction conditions which are specifically necessary for carrying out the N-oxidation.

The compounds of the formula IV can be prepared, for example, from compounds of the formula V,



in which R1, R2, R3, R31, R4, R5 and R51 have the abovementioned meanings, by reduction of the nitro group.

The reduction is carried out in a manner known to the person skilled in the art, for example as described in *J. Org. Chem.* 1962, 27, 4426 or as described in the following examples.

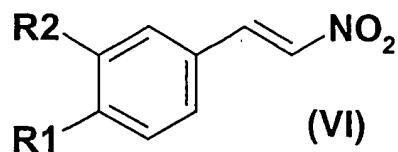
The reduction can be carried out, for example, by catalytic hydrogenation, e.g. in the presence of Raney nickel, in a lower alcohol such as methanol or ethanol at room temperature and under normal or elevated pressure. If desired, a catalytic amount of an acid, such as, for example, hydrochloric acid, can be added to the solvent. Preferably, however, the reduction is carried out using metals such as zinc or iron with organic acids such as acetic acid or mineral acids such as hydrochloric acid.

The compounds of the formula IV in which R1, R2, R3, R31 and R4 have the meanings indicated above and R5 and R51 together represent an additional bond can be prepared from the corresponding compounds of the formula V by selective reduction of the nitro group in a manner known to the person

skilled in the art, for example in the presence of Raney nickel in a lower alcohol as solvent using hydrazine hydrate as a hydrogen donor.

The compounds of the formula V, in which R1, R2, R3, R31 and R4 have the meanings indicated above and R5 and R51 are hydrogen, are either known or can be prepared from corresponding compounds of the formula V in which R5 and R51 together are an additional bond. The reaction can be carried out in a manner known to the person skilled in the art, preferably by hydrogenation in the presence of a catalyst, such as, for example, palladium on active carbon, e.g. as described in J. Chem. Soc. (C), 1971, 1805-1808.

The compounds of the formula V, in which R5 and R51 together are an additional bond, are either known or can be obtained by the reaction of compounds of the formula VI,



in which R1 and R2 have the meanings mentioned above, with compounds of the formula VII,



in which R3, R31 and R4 have the meanings mentioned above.

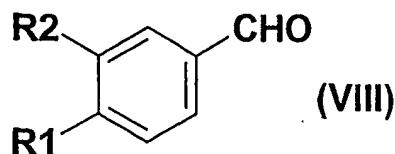
Compounds of the formula V in which R5 and R51 are together an additional bond and R3 and R31 are together a 1-4C-alkylene group can be obtained, for example, by reaction of cyclic compounds of the formula VII, in which R4 has the meanings indicated above and R3 and R31 together are a 1-4C-alkylene group [e.g. cyclohexa-1,3-diene, 2,3-dimethylcyclohexa-1,3-diene, cyclohepta-1,3-diene, 2,3-dimethylcyclohepta-1,3-diene or cycloocta-1,3-diene], with compounds of the formula VI in which R1 and R2 have the abovementioned meanings.

The cycloaddition is in this case carried out in a manner known to the person skilled in the art according to Diels-Alder, e.g. as described in J. Amer. Chem. Soc. 1957, 79, 6559 or in J. Org. Chem. 1952, 17, 581 or as described in the following examples.

Compounds of the formula V obtained in the cycloaddition, in which the phenyl ring and the nitro group are trans to one another, can be converted in a manner known to the person skilled in the art into the corresponding cis compounds, e.g. as described in J. Amer. Chem. Soc. 1957, 79, 6559 or as described in the following examples.

The compounds of the formulae VI and VII are either known or can be prepared in a known manner. The compounds of the formula VI can be prepared, for example, in a manner known to the person skilled in the art from corresponding compounds of the formula VIII as described, for example, in J. Chem. Soc. 1951, 2524 or in J. Org. Chem. 1944, 9, 170 or as described in the following examples.

The compounds of the formula VIII,



in which R1 and R2 have the meanings indicated above, are either known or can be prepared in a manner known to the person skilled in the art, as described, for example, in Ber. Dtsch. Chem. Ges. 1925, 58, 203.

The isolation and purification of the substances according to the invention is carried out in a manner known per se, e.g. by distilling off the solvent in vacuo and recrystallizing the resulting residue from a suitable solvent or subjecting it to one of the customary purification methods, such as, for example, column chromatography on suitable support material.

Salts are obtained by dissolving the free compound in a suitable solvent (e.g. a ketone, such as acetone, methyl ethyl ketone or methyl isobutyl ketone, an ether, such as diethyl ether, tetrahydrofuran or dioxane, a chlorinated hydrocarbon, such as methylene chloride or chloroform, or a low molecular weight aliphatic alcohol such as ethanol or isopropanol) which contains the desired acid or base, or to which the desired acid or base is then added. The salts are obtained by filtering, reprecipitating, precipitating with a nonsolvent for the addition salt or by evaporating the solvent. Salts obtained can be converted by alkalization or by acidification into the free compounds, which in turn can be converted into salts. In this way, pharmacologically intolerable salts can be converted into pharmacologically tolerable salts.

The following examples serve to illustrate the invention further without restricting it. Likewise, further compounds of the formula I, whose preparation is not explicitly described, can be prepared in an analogous manner or in a manner familiar per se to the person skilled in the art using customary process techniques.

In the examples, m.p stands for melting point, h for hour(s), RT for room temperature, EF for empirical formula, MW for molecular weight, calc. for calculated, fnd. for found. The compounds mentioned in the examples and their salts are a preferred subject of the invention.

Examples

Final products

1. (-)-cis-8,9-Dimethoxy-6-[(3-methoxycarbonyl-5-nitro)phenyl]-1,2,3,4,4a,10b-hexahydro-phenanthridine

1.5 g of *(–)-cis-N-[2-(3,4-dimethoxyphenyl)cyclohexyl]-[3-methoxycarbonyl-5-nitro)benzamide* (compound A1) are dissolved in 30 ml of acetonitrile and 1.5 ml of phosphorus oxychloride and the solution is stirred at 80°C for 3 h. The reaction mixture is concentrated under reduced pressure, and the residue is taken up in ethyl acetate and extracted with saturated sodium hydrogencarbonate solution and water. The organic phase is dried using sodium sulfate and concentrated. The residue is recrystallized from ethyl acetate.

EF: C₂₃H₂₄N₂O₆; MW: 424.46

Specific rotation: $[\alpha]_D^{20} = -341^\circ$ (c = 0.2 DMF)

Elemental analysis: calc.: C 65.08 H 5.70 N 6.60
fnd. : C 65.04 H 5.73 N 6.52

Starting compounds

A1. (-)-cis-N-[2-(3,4-Dimethoxyphenyl)cyclohexyl]-3-methoxycarbonyl-5-nitrobenzamide

2.0 g of (-)-cis-1,2-dimethoxy-4-(2-aminocyclohexyl)benzene (compound B2) are dissolved in 50 ml of dichloromethane and 10 ml of triethylamine. A solution of 2.4 g of 3-methoxycarbonyl-5-nitrobenzoyl chloride in 50 ml of dichloromethane is added dropwise at RT, and the mixture is extracted after stirring overnight with 50 ml each of water, 2N hydrochloric acid, satd. sodium hydrogencarbonate solution and water again. The organic phase is dried using sodium sulfate and concentrated and the residue is crystallized from ethanol.

M.p.: 131-133°C

Specific rotation: $[\alpha]_D^{20} = -120^\circ$ (c = 0.2 ethanol)

B1. (+/-)-cis-1,2-Dimethoxy-4-(2-aminocyclohexyl)benzene

125 g of (+/-)-cis-1,2-dimethoxy-4-(2-nitrocyclohexyl)benzene and 120 g of zinc powder or granules are suspended in 1300 ml of ethanol. 220 ml of acetic acid are added dropwise at boiling heat. The precipitate is filtered off with suction and washed with ethanol, and the filtrate is concentrated under reduced pressure. The residue is taken up in hydrochloric acid and extracted with toluene. The aqueous phase is rendered alkaline using 50% strength sodium hydroxide solution, the precipitate is filtered off with suction and the filtrate is extracted with toluene. The organic phase is dried using sodium sulfate and concentrated. 98 g of the title compound are obtained as a crystallizing oil.

Alternatively:

8.5 g of (+/-)-cis-1,2-dimethoxy-4-(2-nitrocyclohexyl)benzene are dissolved in 400 ml of methanol and treated at RT with 7 ml of hydrazine hydrate and 2.5 g of Raney nickel in portions in the course of 8 h. After stirring overnight at RT, the reaction mixture is filtered, the filtrate is concentrated and the residue is chromatographed on silica gel using a mixture of toluene/ethyl acetate/triethylamine = 4/2/0.5. The title compound is obtained as an oil.

B2. (-)-cis-1,2-Dimethoxy-4-(2-aminocyclohexyl)benzene

12.0 g of (+/-)-cis-1,2-dimethoxy-4-(2-aminocyclohexyl)benzene and 6.2 g of (-)-mandelic acid are dissolved in 420 ml of dioxane and 60 ml of tetrahydrofuran and the solution is stirred overnight at RT. The solid is filtered off with suction, dried, treated with 100 ml of saturated sodium hydrogencarbonate solution and extracted with ethyl acetate. The organic phase is dried using sodium sulfate and concentrated under reduced pressure. 4.8 g of the title compound are obtained of m.p.: 80-81.5°C.

Specific rotation: $[\alpha]_D^{20} = -58.5^\circ\text{C}$ (c = 1, ethanol).

C1. (+/-)-cis-1,2-Dimethoxy-4-(2-nitrocyclohex-4-enyl)benzene

10.0 g of (+/-)-trans-1,2-dimethoxy-4-(2-nitrocyclohex-4-enyl)benzene and 20.0 g of potassium hydroxide are dissolved in 150 ml of ethanol and 35 ml of dimethylformamide. A solution of 17.5 ml of conc. sulfuric acid in 60 ml of ethanol is then added dropwise such that the internal temperature does not exceed 4°C. After stirring for 1 h, the mixture is added to 1 l of ice water, the precipitate is filtered off with suction, washed with water and dried, and the crude product is recrystallized from ethanol. 8.6 g of the title compound of m.p. 82.5-84°C are obtained.

C2. (+/-)-cis-1,2-Dimethoxy-4-(2-nitrocyclohexyl)benzene

8.4 g of (+/-)-cis-1,2-dimethoxy-4-(2-nitrocyclohex-4-enyl)benzene are dissolved in 450 ml of methanol, treated with 2 ml of conc. hydrochloric acid and hydrogenated after addition of 500 mg of 10% strength Pd/C. The reaction mixture is filtered and the filtrate is concentrated. M.p.: 84-86.5°C.

D1. (+/-)-trans-1,2-Dimethoxy-4-(2-nitrocyclohex-4-enyl)benzene

50.0 g of 3,4-dimethoxy- ω -nitrostyrene and 1.0 g (9.1 mmol) of hydroquinone are suspended in 200 ml of abs. toluene and treated at -70°C with 55.0 g (1.02 mol) of liquid 1,3-butadiene. The mixture is stirred at 160°C for 6 days in an autoclave and then cooled. Some of the solvent is removed on a rotary evaporator, and the resulting precipitate is filtered off with suction and recrystallized in ethanol. M.p.: 113.5-115.5°C.

E1. 3,4-Dimethoxy- ω -nitrostyrene

207.0 g of 3,4-dimethoxybenzaldehyde, 100.0 g of ammonium acetate and 125 ml of nitromethane are heated to boiling for 3-4 h in 1.0 l of glacial acetic acid. After cooling in an ice bath, the precipitate is filtered off with suction, rinsed with glacial acetic acid and petroleum ether and dried. M.p.: 140-141°C. Yield: 179.0 g.

Commercial applicability

The compounds according to the invention have valuable pharmacological properties which make them commercially utilizable. As selective cyclic nucleotide phosphodiesterase (PDE) inhibitors (namely of type 4), they are suitable on the one hand as bronchial therapeutics (for the treatment of airway obstructions on account of their dilating but also on account of their respiratory rate- or respiratory drive-increasing action) and for the elimination of erectile dysfunction on account of the vasodilating action, but on the other hand especially for the treatment of disorders, in particular of inflammatory nature, e.g. of the airways (asthma prophylaxis), of the skin, of the central nervous system, of the intestine, of the eyes and of the joints, which are mediated by mediators such as histamine, PAF (platelet-activating factor), arachidonic acid derivatives such as leukotrienes and prostaglandins, cytokines, interleukins, chemokines, alpha-, beta- and gamma-interferon, tumor necrosis factor (TNF) or oxygen radicals and proteases. The compounds according to the invention are distinguished here by low toxicity, good enteral absorption (high bioavailability), a large therapeutic breadth and the absence of significant side-effects.

On account of their PDE-inhibiting properties, the compounds according to the invention can be employed in human and veterinary medicine and therapeutics, where they can be used, for example, for the treatment and prophylaxis of the following illnesses: acute and chronic (in particular inflammatory and allergen-induced) airway disorders of various origins (bronchitis, allergic bronchitis, bronchial asthma, emphysema, COPD); dermatoses (especially of proliferative, inflammatory and allergic type) such as, for example, psoriasis (vulgaris), toxic and allergic contact eczema, atopic eczema, seborrheic eczema, lichen simplex, sunburn, pruritus in the anogenital area, alopecia areata, hypertrophic scars, discoid lupus erythematosus, follicular and wide-area pyodermias, endogenous and exogenous acne, acne rosacea and other proliferative, inflammatory and allergic skin disorders; disorders which are based on an excessive release of TNF and leukotrienes, e.g. disorders of the arthritis type (rheumatoid arthritis, rheumatoid spondylitis, osteoarthritis and other arthritic conditions), disorders of the immune system (AIDS, multiple sclerosis), graft-versus-host reactions, transplant rejection reactions, symptoms of shock [septic shock, endotoxin shock, gram-negative sepsis, toxic shock syndrome and ARDS (adult respiratory distress syndrome)], and generalized inflammations in the gastrointestinal area (Crohn's disease and ulcerative colitis); disorders which are based on allergic and/or chronic, faulty immunological reactions in the area of the upper airways (pharynx, nose) and the adjacent regions (paranasal sinuses, eyes), such as, for example, allergic rhinitis/sinusitis, chronic rhinitis/sinusitis, allergic conjunctivitis and nasal polyps; but also disorders of the heart which can be treated by PDE inhibitors, such as, for example, cardiac insufficiency, or disorders which can be treated on account of the tissue-relaxant action of the PDE inhibitors, such as, for example, erectile dysfunction or colics of the kidneys and the ureters in connection with kidney stones. In addition, the compounds according to the invention can be employed for the treatment of diabetes insipidus and disorders in connection with disturbances of brain metabolism, such as, for example, cerebral senility, senile dementia (Alzheimer's dementia), multiin-

farct dementia or alternatively disorders of the CNS, such as, for example, depressions or arteriosclerotic dementia.

The invention further relates to the compounds according to the invention for use in the treatment of mammals, including man, which are suffering from one of the abovementioned illnesses. The process comprises administering to the sick mammal a therapeutically efficacious and pharmacologically tolerable amount of one or more of the compounds according to the invention.

The invention further relates to the compounds according to the invention for use in the treatment and/or prophylaxis of illnesses, in particular the illnesses mentioned.

The invention likewise relates to the use of the compounds according to the invention for the production of medicaments which are employed for the treatment and/or prophylaxis of the illnesses mentioned.

Medicaments for the treatment and/or prophylaxis of the illnesses mentioned, which contain one or more of the compounds according to the invention, are furthermore a subject of the invention.

A further subject of the invention is a commercial product, consisting of a customary secondary pack, a primary pack containing the medicament (for example an ampoule or a blister pack) and, if desired, a pack insert, the medicament exhibiting antagonistic action against cyclic nucleotide phosphodiesterases of type 4 (PDE4) and leading to the attenuation of the symptoms of illnesses which are connected with cyclic nucleotide phosphodiesterases of type 4, and the suitability of the medicament for the prophylaxis or treatment of illnesses which are connected with cyclic nucleotide phosphodiesterases of type 4 being indicated on the secondary pack or on the pack insert of the commercial product, and the medicament containing one or more compounds of the formula I according to the invention. The secondary pack, the primary pack containing the medicament and the pack insert otherwise comply with what would be regarded as standard to the person skilled in the art for medicaments of this type.

The medicaments are prepared by processes which are known per se and familiar to the person skilled in the art. As medicaments, the compounds according to the invention (= active compounds) are either employed as such, or preferably in combination with suitable pharmaceutical excipients, e.g. in the form of tablets, coated tablets, capsules, suppositories, patches, emulsions, suspensions, gels or solutions, the active compound content advantageously being between 0.1 and 95%.

The person skilled in the art is familiar on the basis of his/her expert knowledge with the excipients which are suitable for the desired pharmaceutical formulations. In addition to solvents, gel-forming agents, ointment bases and other active compound vehicles, it is possible to use, for example, antioxidants, dispersants, emulsifiers, preservatives, solubilizers or permeation promoters.

For the treatment of disorders of the respiratory tract, the compounds according to the invention are preferably also administered by inhalation in the form of an aerosol; the aerosol particles of solid, liquid or mixed composition preferably having a diameter of 0.5 to 10 μm , advantageously of 2 to 6 μm .

Aerosol generation can be carried out, for example, by pressure-driven jet atomizers or ultrasonic atomizers, but advantageously by propellant-driven metered aerosols or propellant-free administration of micronized active compounds from inhalation capsules.

Depending on the inhaler system used, in addition to the active compounds the administration forms additionally contain the required excipients, such as, for example, propellants (e.g. Frigen in the case of metered aerosols), surface-active substances, emulsifiers, stabilizers, preservatives, flavorings, fillers (e.g. lactose in the case of powder inhalers) or, if appropriate, further active compounds.

For the purposes of inhalation, a large number of apparatuses are available with which aerosols of optimum particle size can be generated and administered, using an inhalation technique which is as right as possible for the patient. In addition to the use of adaptors (spacers, expanders) and pear-shaped containers (e.g. Nebulator®, Volumatic®), and automatic devices emitting a puffer spray (Autohaler®), for metered aerosols, in particular in the case of powder inhalers, a number of technical solutions are available (e.g. Diskhaler®, Rotadisk®, Turbohaler® or the inhaler described in European Patent Application EP 0 505 321), using which an optimal administration of active compound can be achieved.

For the treatment of dermatoses, the compounds according to the invention are in particular used in the form of those medicaments which are suitable for topical application. For the production of the medicaments, the compounds according to the invention (= active compounds) are preferably mixed with suitable pharmaceutical excipients and further processed to give suitable pharmaceutical formulations. Suitable pharmaceutical formulations which may be mentioned are, for example, powders, emulsions, suspensions, sprays, oils, ointments, fatty ointments, creams, pastes, gels or solutions.

The medicaments according to the invention are prepared by processes known per se. Dosage of the active compounds takes place in the order of magnitude customary for PDE inhibitors. Thus topical application forms (such as, for example, ointments) for the treatment of dermatoses contain the active compounds in a concentration of, for example, 0.1-99%. The dose for administration by inhalation is customarily between 0.1 and 3 mg per day. The customary dose in the case of systemic therapy (p.o. or i.v.) is between 0.03 and 3 mg per kilogram per day.

Biological investigations

The second messenger cyclic AMP (cAMP) is well-known for inhibiting inflammatory and immunocompetent cells. The PDE4 isoenzyme is broadly expressed in cells involved in the initiation and propagation of inflammatory diseases (H Tenor and C Schudt, in „Phosphodiesterase Inhibitors“, 21-40, „The Handbook of Immunopharmacology“, Academic Press, 1996), and its inhibition leads to an increase of the intracellular cAMP concentration and thus to the inhibition of cellular activation (JE Souness et al., Immunopharmacology 47: 127-162, 2000).

The antiinflammatory potential of PDE4 inhibitors *in vivo* in various animal models has been described (MM Teixeira, TiPS 18: 164-170, 1997). For the investigation of PDE4 inhibition on the cellular level (*in vitro*), a large variety of proinflammatory responses can be measured. Examples are the superoxide production of neutrophilic (C Schudt et al., Arch Pharmacol 344: 682-690, 1991) or eosinophilic (A Hatzelmann et al., Brit J Pharmacol 114: 821-831, 1995) granulocytes, which can be measured as luminol-enhanced chemiluminescence, or the synthesis of tumor necrosis factor- α in monocytes, macrophages or dendritic cells (Gantner et al., Brit J Pharmacol 121: 221-231, 1997, and Pulmonary Pharmacol Therap 12: 377-386, 1999). In addition, the immunomodulatory potential of PDE4 inhibitors is evident from the inhibition of T-cell responses like cytokine synthesis or proliferation (DM Essayan, Biochem Pharmacol 57: 965-973, 1999). Substances which inhibit the secretion of the afore-mentioned proinflammatory mediators are those which inhibit PDE4. PDE4 inhibition by the compounds according to the invention is thus a central indicator for the suppression of inflammatory processes.

Method for measuring inhibition of PDE4 activity

PDE4 activity was determined as described by Thompson et al. (Adv Cycl Nucl Res 10: 69-92, 1979) with some modifications (Bauer and Schwabe, Naunyn-Schmiedeberg's Arch Pharmacol 311: 193-198, 1980). At a final assay volume of 200 μ l (96well microtiter plates) the assay mixture contained 20 mM Tris (pH 7.4), 5 mM MgCl₂, 0.5 μ M cAMP, [³H]cAMP (about 30,000 cpm/assay), the test compound and an aliquot of cytosol from human neutrophils which mainly contains PDE4 activity as described by Schudt et al. (Naunyn-Schmiedeberg's Arch Pharmacol 344: 682-690, 1991); the PDE3-specific inhibitor Motapizone (1 μ M) was included to suppress PDE3 activity originating from contaminating platelets. Serial dilutions of the compounds were prepared in DMSO and further diluted 1:100 (v/v) in the assays to obtain the desired final concentrations of the inhibitors at a DMSO concentration of 1 % (v/v) which by itself only slightly affected PDE4 activity.

After preincubation for 5 min at 37°C, the reaction was started by the addition of substrate (cAMP) and the assays were incubated for further 15 min at 37°C. 50 μ l of 0.2 N HCl was added to stop the reaction and the assays were left on ice for about 10 min. Following incubation with 25 μ g 5'-nucleotidase (*Crotalus atrox* snake venom) for 10 min at 37°C, the assays were loaded on QAE Sephadex A-25 (1 ml bed

volume). The columns were eluted with 2 ml of 30 mM ammonium formate (pH 6.0) and the eluate was counted for radioactivity. Results were corrected for blank values (measured in the presence of denatured protein) which were below 5 % of total radioactivity. The amount of cyclic nucleotides hydrolyzed did not exceed 30 % of the original substrate concentration. The IC_{50} -values for the compounds according to the invention for the inhibition of the PDE4 activity were determined from the concentration-inhibition curves by nonlinear-regression.

The inhibitory values determined for the compounds according to the invention follow from the following table A, in which the numbers of the compounds correspond to the numbers of the examples.

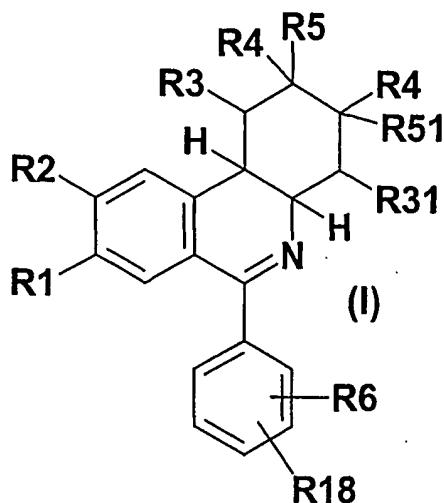
Table A

Inhibition of PDE4 acitivity [measured as $-\log IC_{50}$ (mol/l)]

Compound	$-\log IC_{50}$
1	8.14

Patent claims

1. A compound of the formula I,



in which

R1 is hydroxyl, 1-4C-alkoxy, 3-7C-cycloalkoxy, 3-7C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R2 is hydroxyl, 1-4C-alkoxy, 3-7C-cycloalkoxy, 3-7C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-4C-alkoxy,

or in which

R1 and R2 together are a 1-2C-alkylenedioxy group,

R3 is hydrogen or 1-4C-alkyl,

R31 is hydrogen or 1-4C-alkyl,

or in which

R3 and R31 together are a 1-4C-alkylene group,

R4 is hydrogen or 1-4C-alkyl,

R5 is hydrogen,

R51 is hydrogen,

or in which

R5 and R51 together represent an additional bond,

R6 is $\text{SO}_2\text{N}(\text{R7})\text{R8}$, COOR9 , $\text{CON}(\text{R10})\text{R11}$ or a R15-substituted tetrazol-5-yl radical, where

R7 and R8 independently of one another are hydrogen, 1-7C-alkyl, 3-7C-cycloalkyl, 3-7C-cycloalkylmethyl or a phenyl radical which is unsubstituted or substituted by R12 and/or R13, or where R7 and R8 together and including the nitrogen atom to which both are bonded are a 1-pyrrolidinyl, 1-piperidyl, 1-hexahydroazepinyl or 4-morpholinyl radical,

R9 is hydrogen, 1-7C-alkyl, 3-7C-cycloalkyl or 3-7C-cycloalkylmethyl, and where either

R10 and R11 independently of one another are hydrogen, 1-7C-alkyl, 3-7C-cycloalkyl or 3-7C-cycloalkylmethyl,

or

R10 is hydrogen or 1-4C-alkyl and

R11 is a phenyl radical which is unsubstituted or substituted by R12 and/or R13 or a pyridyl radical which is unsubstituted or substituted by R14, where

R12 is hydroxyl, halogen, 1-4C-alkyl or 1-4C-alkoxy,

R13 is hydroxyl, halogen, nitro, cyano, carboxyl, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, 1-4C-alkoxycarbonyl, 1-4C-alkylcarbonyloxy, amino, mono- or di-1-4C-alkylamino, amino-carbonyl, mono- or di-1-4C-alkylaminocarbonyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R14 is halogen, nitro, carboxyl, 1-4C-alkoxy, 1-4C-alkoxycarbonyl, 1-4C-alkyl, trifluoromethyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R15 is hydrogen, 1-7C-alkyl, 3-7C-cycloalkyl, 3-7C-cycloalkylmethyl or Ar-1-4C-alkyl where Ar is a phenyl radical which is unsubstituted or substituted by R16 and/or R17, and

R16 and R17 independently of one another are halogen, nitro, cyano, 1-4C-alkyl, trifluoromethyl or 1-4C-alkoxy,

R18 is hydroxyl, halogen, nitro, amino, 1-4C-alkyl or 1-4C-alkoxy,

or the salts, the N-oxide and the salts of the N-oxide of this compound.

2. A compound of the formula I as claimed in claim 1, in which

R1 is 1-2C-alkoxy, 3-5C-cycloalkoxy, 3-5C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-2C-alkoxy,

R2 is 1-2C-alkoxy, 3-5C-cycloalkoxy, 3-5C-cycloalkylmethoxy or completely or predominantly fluorine-substituted 1-2C-alkoxy,

R3 is hydrogen,

R31 is hydrogen,

R4 is hydrogen or 1-2C-alkyl,

R5 is hydrogen,

R51 is hydrogen,

or in which

R5 and R51 together represent an additional bond,

R6 is $\text{SO}_2\text{N}(\text{R7})\text{R8}$, COOR9 , $\text{CON}(\text{R10})\text{R11}$ or a tetrazol-5-yl radical substituted by R15, where

R7 and R8 independently of one another are hydrogen, 1-4C-alkyl, 3-7C-cycloalkyl, 3-7C-cycloalkylmethyl, or a phenyl radical which is unsubstituted or substituted by R12 and/or R13, or where R7 and R8 together and including the nitrogen atom to which both are bonded are a 1-piperidyl or 4-morpholinyl radical,

R9 is hydrogen, 1-7C-alkyl or 3-7C-cycloalkylmethyl, and where either

R10 and R11 independently of one another are hydrogen or 1-7C-alkyl

or

R10 is hydrogen and

R11 is a phenyl radical which is unsubstituted or substituted by R12 and/or R13 or a pyridyl radical which is unsubstituted or substituted by R14, where

R12 is hydroxyl, halogen, 1-4C-alkyl or 1-4C-alkoxy,

R13 is hydroxyl, halogen, nitro, cyano, carboxyl, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, 1-4C-alkoxycarbonyl, 1-4C-alkylcarbonyloxy or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R14 is halogen, 1-4C-alkoxy, 1-4C-alkyl, trifluoromethyl or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R15 is hydrogen, 1-4C-alkyl, 5-7C-cycloalkyl, 3-7C-cycloalkylmethyl or Ar-1-2C-alkyl, where Ar is a phenyl radical which is unsubstituted or substituted by R16 and

R16 is 1-2C-alkyl or 1-2C-alkoxy,

R18 is halogen, nitro, 1-4C-alkyl or 1-4C-alkoxy,

and the salts, the N-oxide and the salts of the N-oxide of this compound.

3. A compound of the formula I as claimed in claim 1, in which

R1 is 1-2C-alkoxy,

R2 is 1-2C-alkoxy,

R3, R31, R4, R5 and R51 are hydrogen,

R6 is $\text{SO}_2\text{N}(\text{R7})\text{R8}$, COOR9 , $\text{CON}(\text{R10})\text{R11}$ or an R15-substituted tetrazol-5-yl radical, where

R7 and R8 independently of one another are hydrogen, 1-4C-alkyl or a phenyl radical which is unsubstituted or substituted by R13,

R9 is hydrogen, 1-7C-alkyl or 3-7C-cycloalkylmethyl, and where either

R10 and R11 independently of one another are hydrogen or 1-4C-alkyl,

or

R10 is hydrogen and

R11 is a phenyl radical which is unsubstituted or substituted by R13 or pyridyl radical which is unsubstituted or substituted by R14, where

R13 is halogen, nitro, cyano, 1-4C-alkyl, trifluoromethyl, 1-4C-alkoxy, 1-4C-alkoxy-carbonyl, 1-4C-alkylcarbonyloxy or completely or predominantly fluorine-substituted 1-4C-alkoxy,

R14 is halogen, 1-4C-alkoxy, 1-4C-alkyl or trifluoromethyl,

R15 is hydrogen, 1-4C-alkyl or 4-methoxyphenyl,

R18 is halogen, nitro, 1-4C-alkyl or 1-4C-alkoxy,

or the salts, the N-oxides and the salts of the N-oxides of this compound.

4. A compound of the formula I as claimed in claim 1, in which
R1 is 1-2C-alkoxy,
R2 is 1-2C-alkoxy,
R3, R31, R4, R5 and R51 are hydrogen,
R6 is SO₂N(R7)R8, COOR9 or CON(R10)R11, where
R7 and R8 independently of one another are hydrogen or 1-4C-alkyl,
R9 is hydrogen or 1-4C-alkyl,
R10 and R11 independently of one another are hydrogen or 1-4C-alkyl,
R18 is halogen, nitro, 1-4C-alkyl or 1-4C-alkoxy,
or the salts, the N-oxide and the salts of the N-oxide of this compound.

5. A compound of the formula I as claimed in claim 1, in which
R1 is methoxy,
R2 is methoxy,
R3, R31, R4, R5 and R51 are hydrogen,
R6 is COOR9, where
R9 is 1-4C-alkyl,
R18 is nitro,
and the salts, the N-oxide and the salts of the N-oxide of this compound.

6. A compound of the formula I as claimed in one of claims 1, 2, 3 or 4, which has the same absolute configuration in positions 4a and 10b as the compound (-)-cis-1,2-dimethoxy-4-(2-aminocyclohexyl)benzene having the optical rotation $[\alpha]_D^{20} = -58.5^\circ$ (c = 1, ethanol), which for its part can be employed as a starting material.

7. A compound of the formula I as claimed in claim 1 for use in the treatment of illnesses.

8. A medicament comprising at least one compound of the formula I as claimed in claim 1 together with customary pharmaceutical excipients and/or vehicles.

9. The use of compounds of the formula I as claimed in claim 1 for the production of medicaments for treating airway disorders.

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C07D221/12 C07D401/10 A61K31/473 A61P11/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 C07D A61K A61P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 35854 A (BYK GULDEN LOMBERG CHEM FAB ;GUTTERER BEATE (DE)) 2 October 1997 (1997-10-02) cited in the application claims	1-9
A	WO 99 05113 A (BYK GULDEN LOMBERG CHEM FAB ;GUTTERER BEATE (DE)) 4 February 1999 (1999-02-04) cited in the application claims	1-9
A	WO 99 05111 A (BYK GULDEN LOMBERG CHEM FAB ;GUTTERER BEATE (DE)) 4 February 1999 (1999-02-04) cited in the application claims	1-9
	---	-/-

 Further documents are listed in the continuation of box C. Patent family members are listed in annex.

° Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *E* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the International filing date but later than the priority date claimed

T later document published after the International filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

& document member of the same patent family

Date of the actual completion of the international search

12 October 2001

Date of mailing of the international search report

23/10/2001

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Chouly, J

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 97 28131 A (BYK GULDEN LOMBERG CHEM FAB ;GUTTERER BEATE (DE)) 7 August 1997 (1997-08-07) cited in the application claims -----	1-9
A	WO 99 05112 A (BYK GULDEN LOMBERG CHEM FAB ;GUTTERER BEATE (DE)) 4 February 1999 (1999-02-04) claims -----	1-9

Patent document cited in search report		Publication date		Patent family member(s)	Publication date
WO 9735854	A	02-10-1997		DE 19613091 A1 AU 718752 B2 AU 2291097 A CA 2250569 A1 WO 9735854 A1 EP 0889886 A1 JP 2000507256 T US 6127378 A	09-10-1997 20-04-2000 17-10-1997 02-10-1997 02-10-1997 13-01-1999 13-06-2000 03-10-2000
WO 9905113	A	04-02-1999		AU 9154698 A EE 200000032 A WO 9905113 A1 EP 1000035 A1 HU 0003311 A2 JP 2001510827 T PL 338452 A1 US 6121279 A	16-02-1999 16-10-2000 04-02-1999 17-05-2000 28-03-2001 07-08-2001 06-11-2000 19-09-2000
WO 9905111	A	04-02-1999		AU 8977098 A EE 200000033 A WO 9905111 A1 EP 0998460 A1 HU 0002510 A2 JP 2001510825 T PL 338339 A1	16-02-1999 16-10-2000 04-02-1999 10-05-2000 28-12-2000 07-08-2001 23-10-2000
WO 9728131	A	07-08-1997		DE 19603321 A1 AU 707058 B2 AU 1719997 A BR 9707233 A CN 1214681 A CZ 9802414 A3 EE 9800223 A WO 9728131 A1 EP 0882021 A1 HU 9900666 A2 JP 2000503996 T NO 983505 A PL 328019 A1 SK 102498 A3 US 6191138 B1	07-08-1997 01-07-1999 22-08-1997 20-07-1999 21-04-1999 16-12-1998 15-12-1998 07-08-1997 09-12-1998 28-06-1999 04-04-2000 11-09-1998 04-01-1999 10-03-1999 20-02-2001
WO 9905112	A	04-02-1999		AU 9066498 A WO 9905112 A1 EP 1000034 A1 JP 2001510826 T US 6214839 B1	16-02-1999 04-02-1999 17-05-2000 07-08-2001 10-04-2001